R-Mode Baltic

Testbed for safe navigation at the Baltic Sea

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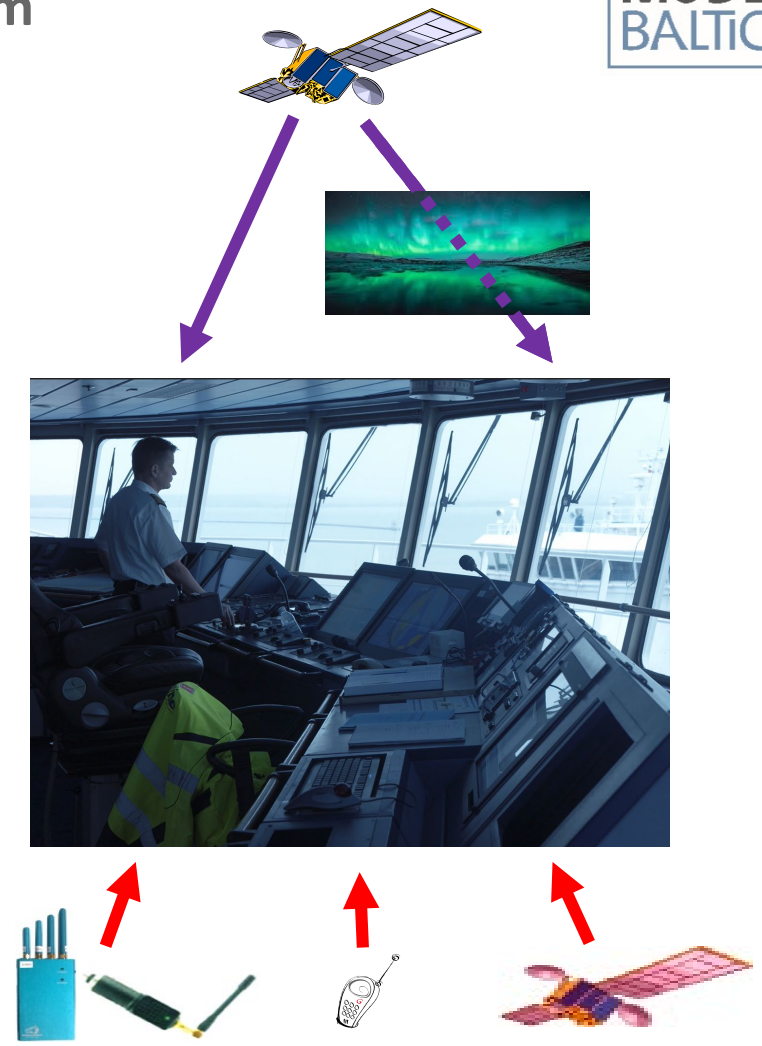
April 14 2021, 14th IALA Symposium

Maritime domain - dominated by GNSS

Safe navigation requires a backup system

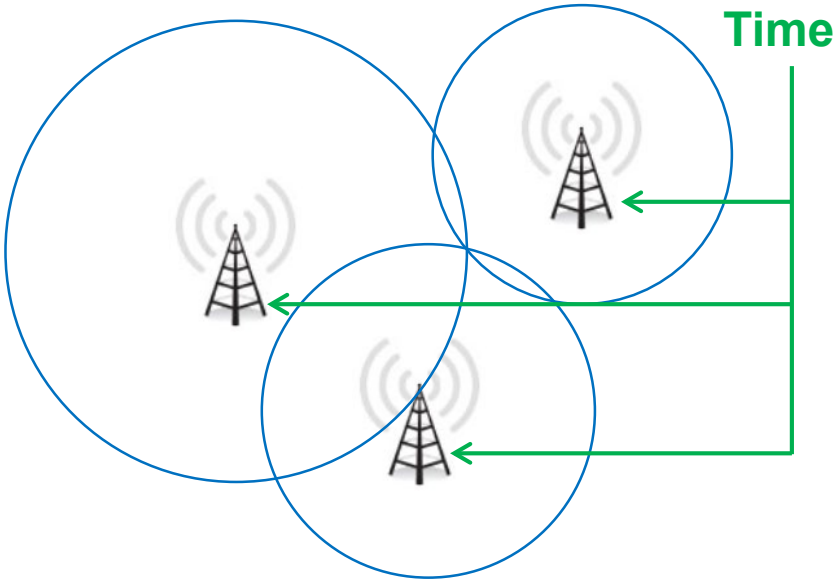
- GNSS
  - primary source for maritime PNT information
  - used in many navigation and communication systems
  - signals vulnerable to unintentional and intentional interferences
- Project siNafa
  - Significant number of radio frequency interferences detected in busy areas



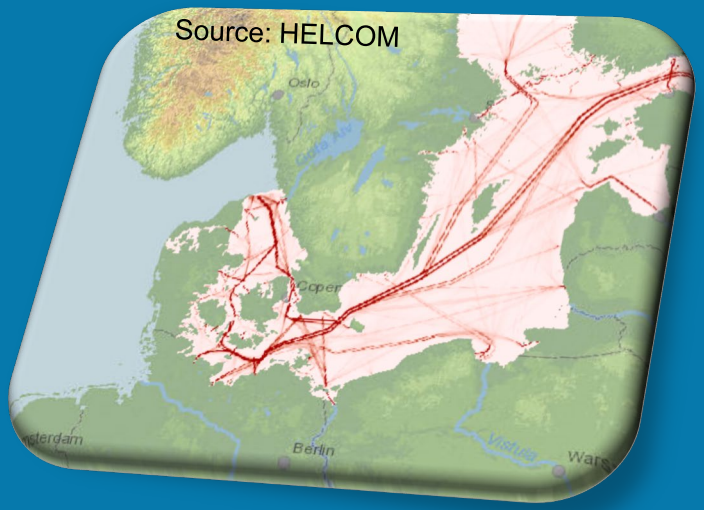
R-Mode terrestrial positioning system

A backup/contingency system to GNSS

- R(anging)-Mode is a positioning system that
  - transmits timely synchronised ranging signals
  - using the communication channel of existing maritime radio infrastructure
- Time of Arrival approach - 3 stations has to be in view
- Possible sources of ranging signals: Medium Frequency (**MF**) marine radio beacons and **VDES** base stations using VHF transmissions



DLR



- Worldwide first combined MF and VHF R-Mode testbed
- Develop ship and shore site equipment
- Show R-Mode can meet the user requirements

Project partner

DLR

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Considered user requirements in the R-Mode Baltic project

Based on IALA Recommendation R-129

The project team will setup a **contingency system** for GNSS, which in case of unavailability of GNSS should allow positioning for at least **2 hours** with:

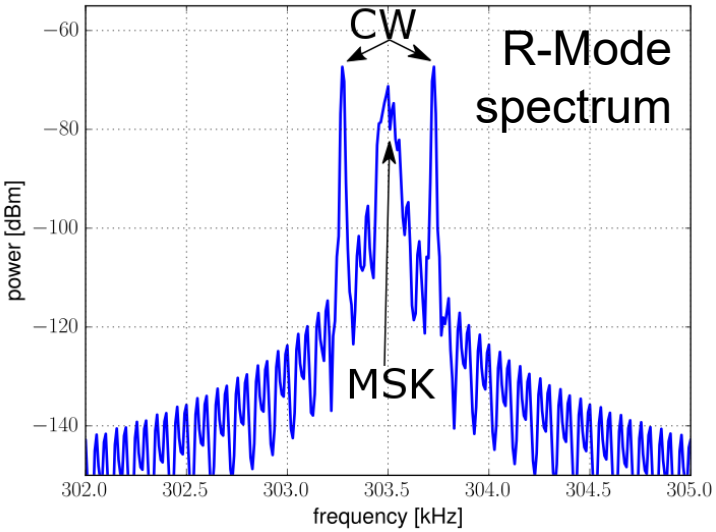
	System level parameters				Service level parameters			
Maritime region	Absolute Accuracy	Integrity			Availability % per 30 days	Continuity % over 15 minutes	Coverage	Fix interval (seconds)
	Horizontal (meters)	Alert limit (meters)	Time to Alarm (seconds)	Integrity Risk (per 3 hours)				
Coastal	100	250	30	10^{-4}	99	N/A[2]	Regional	15
Port approach and restricted waters	10	25	10	10^{-4}	99	99,97	Regional	2
Inland Waterways	10	25	10	10^{-4}	99	99,97	Regional	2

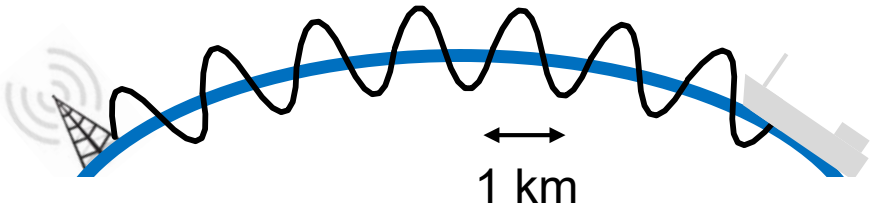
Identified R-Mode system requirements

- Work independently from GNSS (different levels possible)
- Based on existing but modified infrastructure
- No disruption or degradation of the legacy service
- Unlimited user-capacity
- Provide a two-dimensional position fix in WGS84
- Time traceable to UTC
- Provide integrity warning-reporting to the user

Marine radio beacons as source for MF R-Mode signals

- Maritime standard for DGNSS corrections
- Uses MF band: 283.5 – 325 kHz
- Frequency Division Multiple Access (FDMA) with 500 Hz or 1 kHz channel bandwidth
- Range in average 250 km (ground-wave)
- Data channel: MSK modulation with bit length of 5, 10 or 20 ms





R-Mode

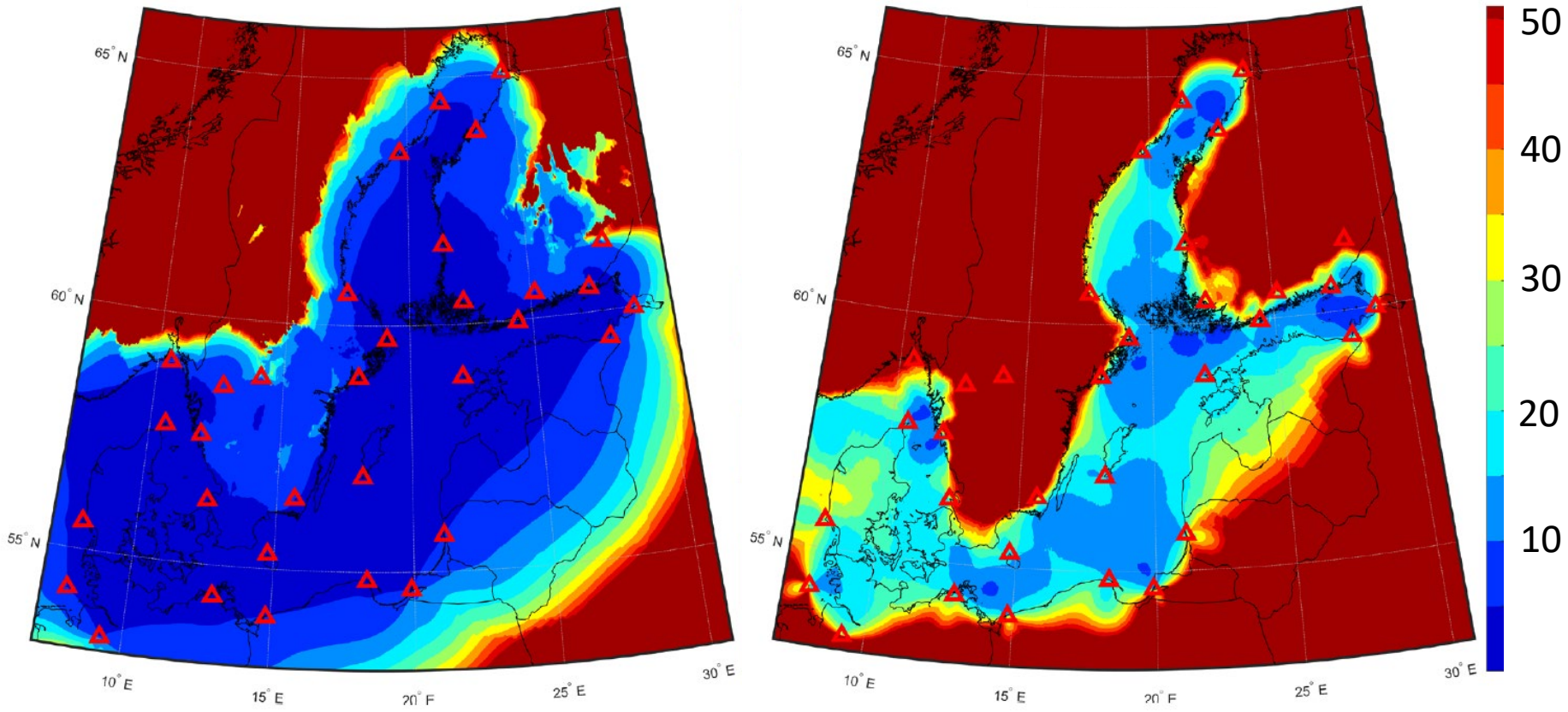
- add aiding carriers (CW) beside the legacy signal
- Pseudorange estimation based on phase measurements of both CW
- Positioning: trilateration

Achievable performance MF R-Mode (theoretical)

Estimated position accuracy based on coverage predictions for the Baltic Sea [1]

Day-time: 95% accuracy [m]

Night-time: 95% accuracy [m]



[1] MF R-Mode coverage prediction and accuracy estimation, GRAD, RPT-07-CH-19, March 2019.

Expected MF R-Mode testbed performance

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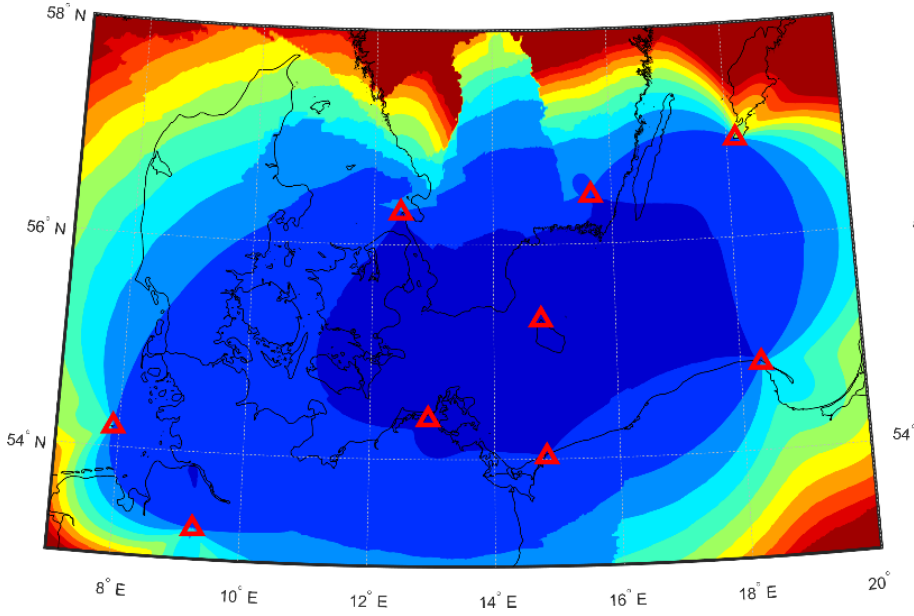
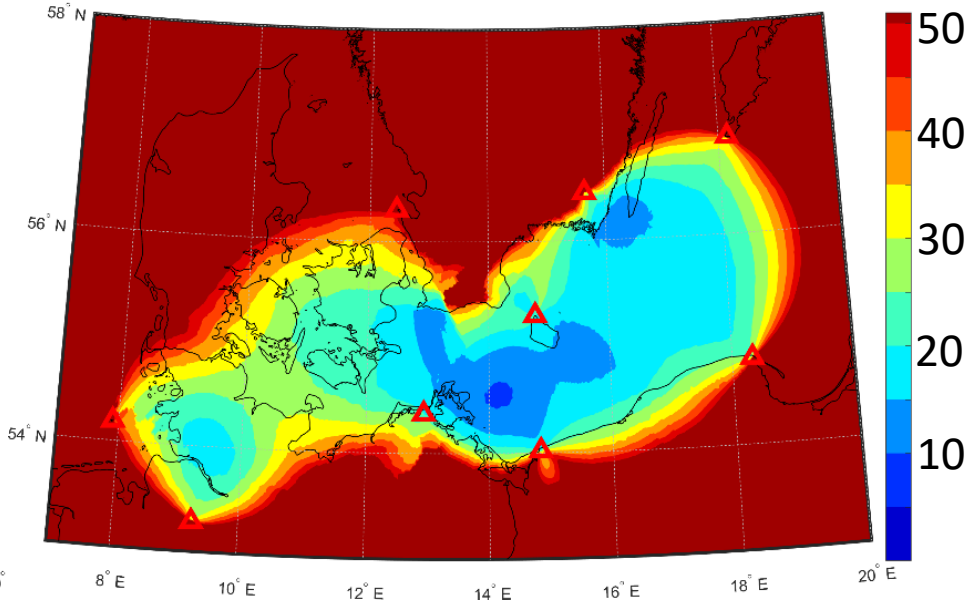


Night-time: 95% accuracy [m]



- Only 8 of 9 transmitters were retrofitted
- One station with reduced transmitter coverage

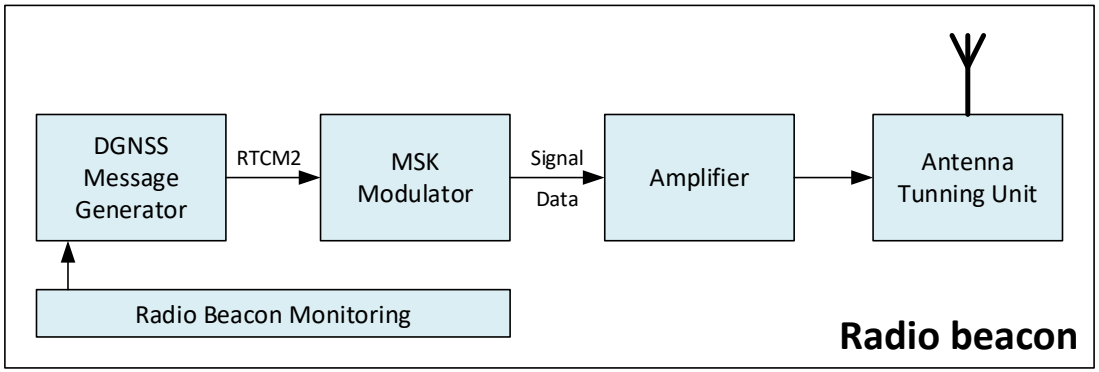
[1] MF R-Mode coverage prediction and accuracy estimation, GRAD, RPT-07-CH-19, March 2019.

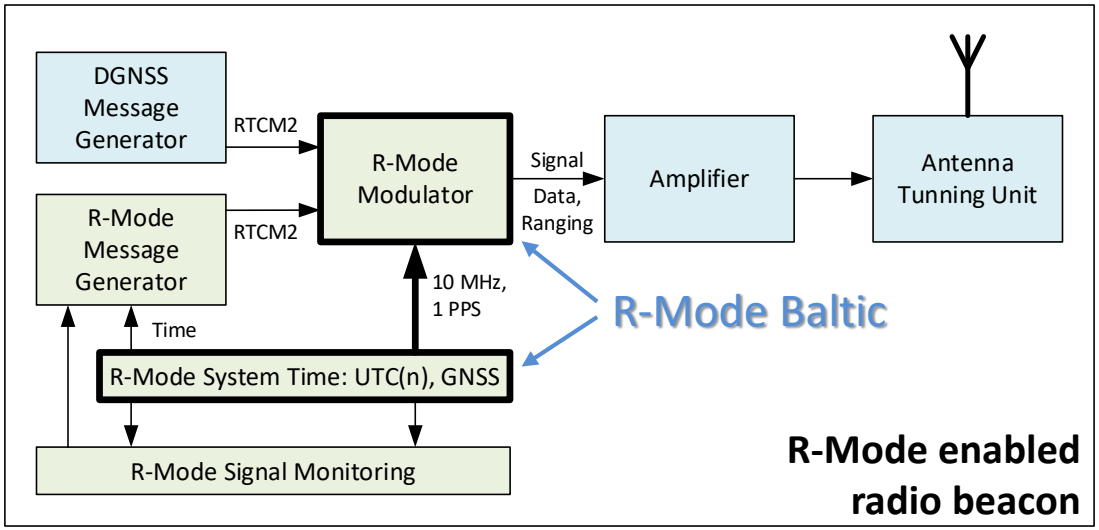
Retrofitting maritime radio beacons

Simplified architecture

- Reuse most of the modules
- Add modules
  - time synchronisation
  - R-Mode signal and message generation
  - monitoring

- Problems that occurred
  - Intermodulation caused by nonlinear amplifiers
  - Instabilities of transmitter chain

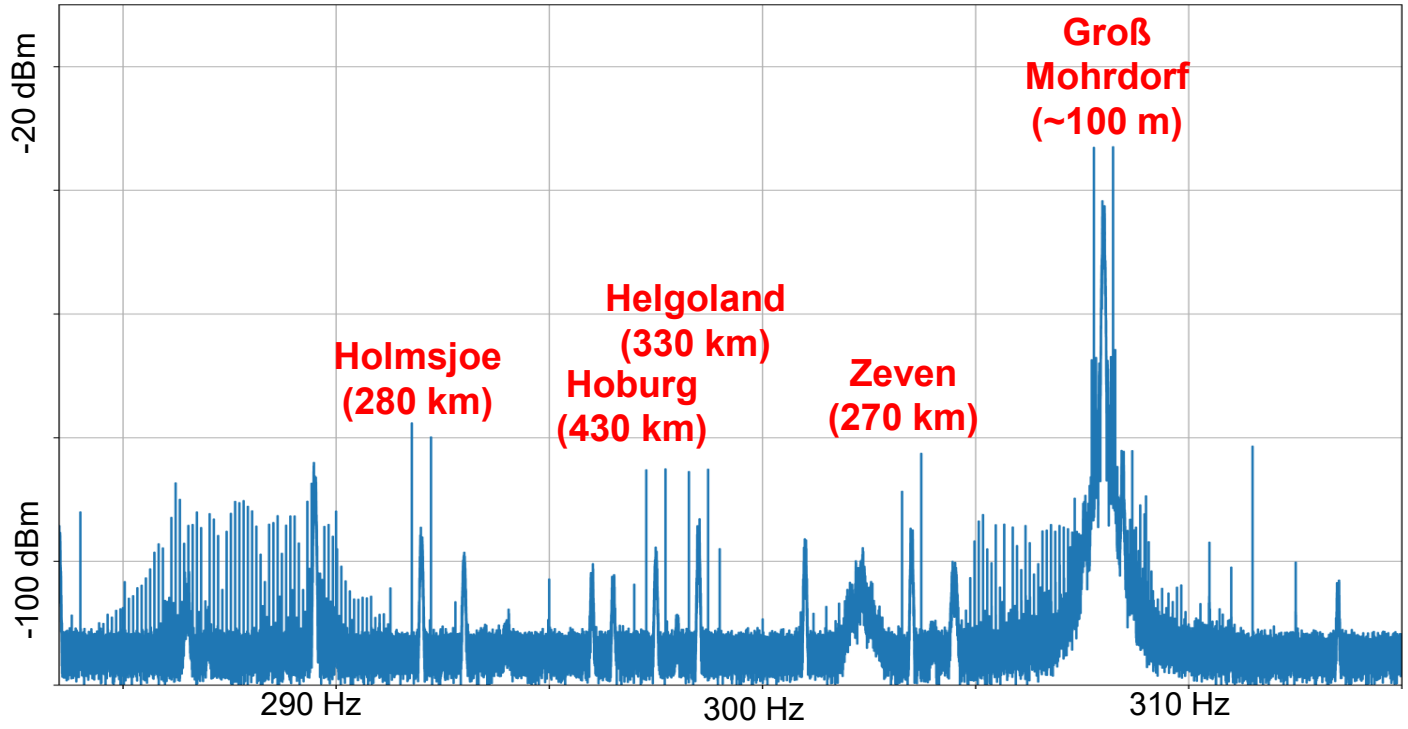




The MF beacon R-Mode testbed in the Baltic (09/2020)

Static measurement in the testbed (06/2020)

Next to German site Groß Mohrdorf

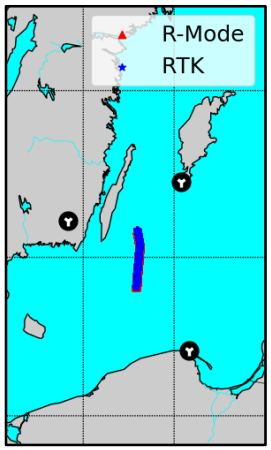


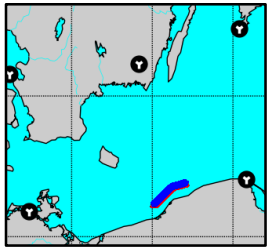
- All R-Mode signals were received (5 of 5 in June 2020)
- Signals up to 430 km could be tracked

First measurement campaign in the MF R-Mode testbed in the Southern Baltic with Swedish ship Fyrbyggaren

- Time: 08/2020
- Used 4 of 7 MF R-Mode sites
- Single point positioning: Self-calibration of R-Mode receiver

- Positioning results for areas with good conditions:
  - Day-time
    - Mean error: 5.2 m
    - 95% accuracy: 12.0 m
  - Night-time
    - Mean error: 30 m
    - 95% accuracy: 64 m

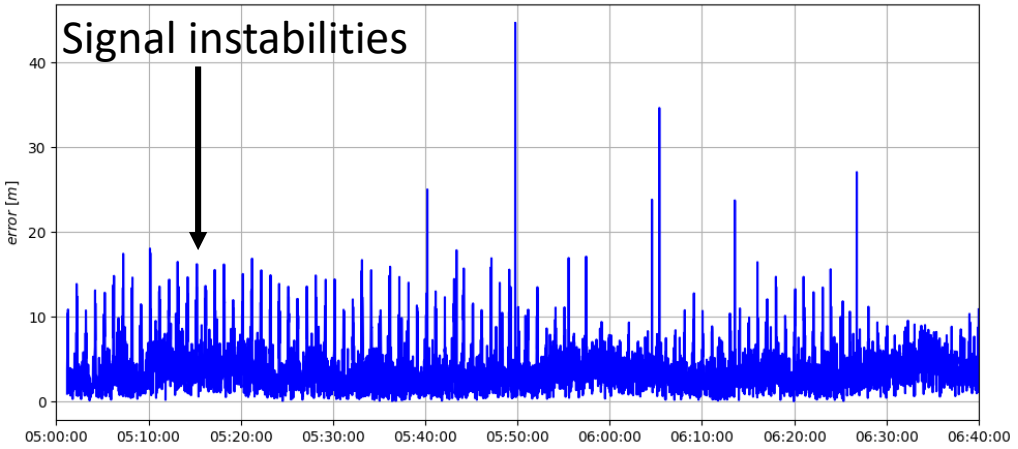




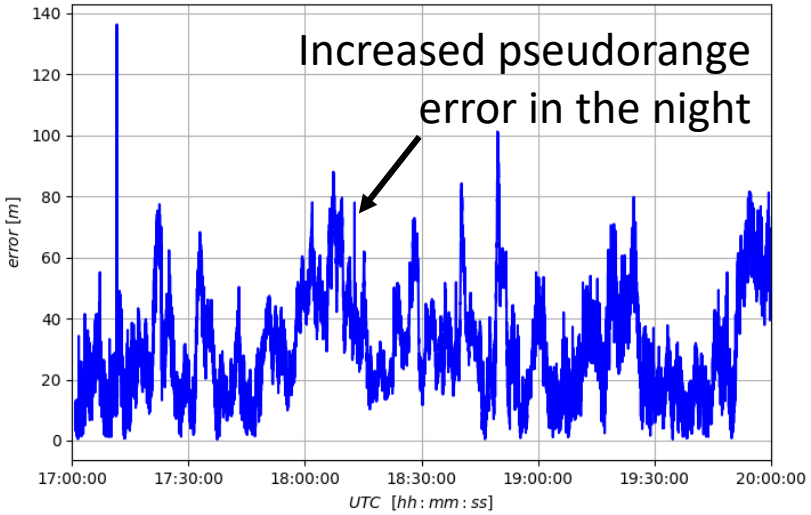
Identified challenges for MF R-Mode

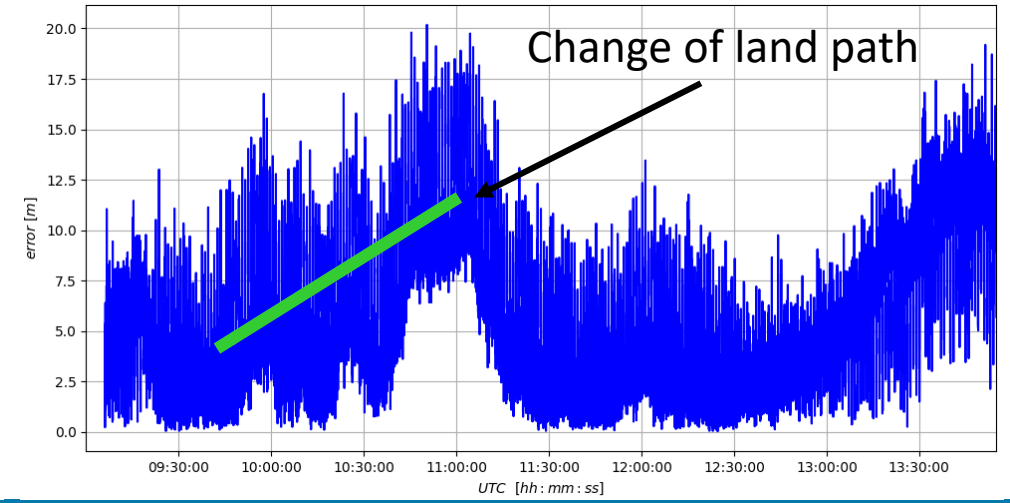
- Stability of transmitted signals
- Mixed propagation path
- Sky-wave induced fading
- Solving ambiguities of aiding carriers
- Accuracy of transmitter site clocks

Positioning performance



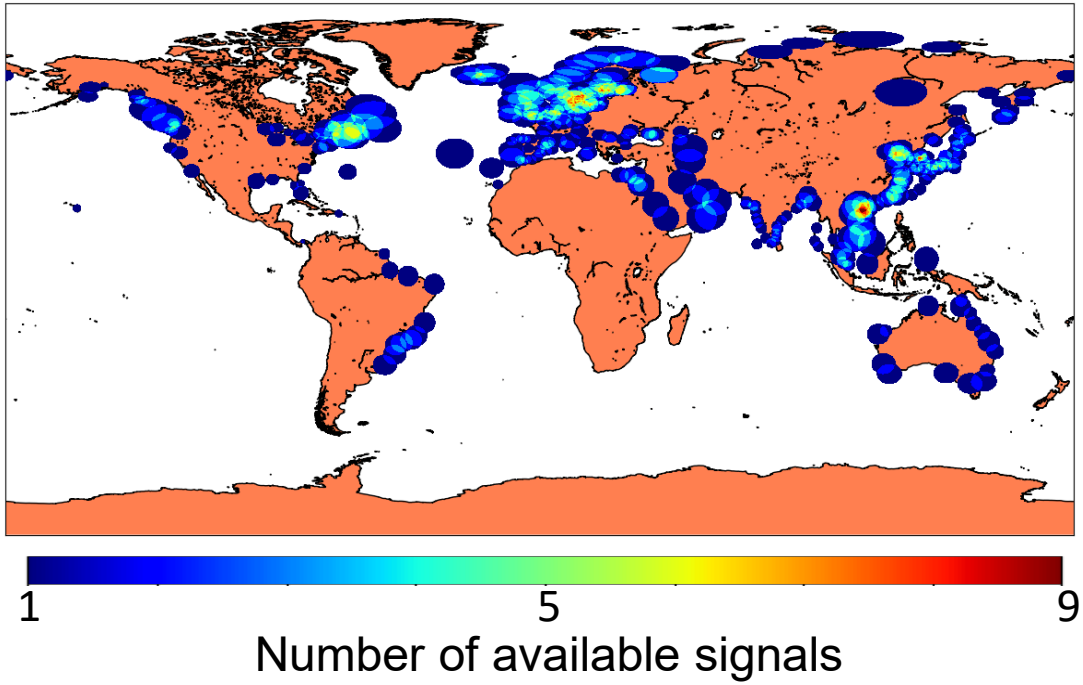
Positioning performance





Worldwide MF R-Mode potential

Based on IALA beacon list of 2019 and AIS Class A data



Signal availability	Worldwide ship traffic [%]	R-Mode use
≥1	68	Integrity external PNT
≥2	53	Positioning
≥3	**40**	**Positioning and timing**
≥4	25	Positioning, timing and integrity

- 2 of 3 ships would benefit from R-Mode signals
- 4 of 10 ships could perform positioning and timing
- VDES R-Mode would further increase the signal availability

Summary

- Medium Frequency and VDES R-Mode are promising approaches to provide GNSS independent positioning and timing

- A testbed with 8 MF R-Mode transmitters is ready for tests in the Southern Baltic Sea
- The testbed will be enlarged by 4 VDES R-Mode transmitters in 2021

- Theory: MF R-Mode performance is sufficient to support coastal navigation in the Baltic Sea with a contingency or backup system
- Experiments support theory for good conditions

- Land and ship site equipment have to be improved to meet the theory and the user requirements under challenging conditions

R-Mode Baltic conference

Save the date May 18 2021

The R-Mode Baltic project teams invites you to the virtual project conference on May 18 2021.

- Topics
  - MF R-Mode
  - VDES R-Mode
  - R-Mode Baltic testbed
  - R-Mode hardware
  - R-Mode applications

- More information will be soon available on our website:

https://www.r-mode-baltic.eu

Thanks for your attention

https://www.r-mode-baltic.eu

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Project partner

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